Article

Packed cell volume and heart rate to predict medical and surgical cases and their short-term survival in horses with gastrointestinal-induced colic

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Abstract — The objective of this prospective case-control study of 125 horses with gastrointestinal tract-induced colic was to determine whether heart rate (HR) and packed cell volume (PCV) can predict surgical *versus* medical treatment and its short-term survival (time of discharge of the patient). Sixty-four horses were treated medically and 61 surgically (29 small intestinal and 32 large intestinal cases). At admission, both PCV and HR were higher in horses treated surgically than in horses treated medically; however, with longer duration of colic before presentation, the PCV was higher in the small intestinal surgical group only. In addition, both PCV and HR were higher, and the duration of colic was longer in non-survivors compared to survivors. Binary logistic regression demonstrated a significant association between HR and type of treatment, and both HR and PCV were predictive of survival. Simple parameters such as HR and PCV provide useful information for management of colic cases.

Résumé — L'hématocrite et la fréquence cardiaque pour prédire les cas médicaux et chirurgicaux et leur survie à court terme chez les chevaux souffrant de coliques d'origine gastro-intestinale. L'objectif de cette étude prospective cas-témoins de 125 chevaux souffrant de coliques induites par le tractus gastro-intestinal était de déterminer si la fréquence cardiaque (HR) et l'hématocrite (PCV) peuvent prédire le traitement chirurgical par rapport au traitement médical et sa survie à court terme (temps de congé du patient). Soixante-quatre chevaux ont été traités médicalement et 61 chirurgicalement (29 cas d'intestin grêle et 32 cas de gros intestin). A l'admission, le PCV et le HR étaient plus élevés chez les chevaux traités chirurgicalement que chez les chevaux traités médicalement; cependant, avec une durée plus longue des coliques avant la présentation, le PCV était plus élevé uniquement dans le groupe de chirurgie de l'intestin grêle. De plus, le PCV et le HR étaient plus élevés, et la durée des coliques était plus longue chez les non-survivants que chez les survivants. La régression logistique binaire a démontré une association significative entre le HR et le type de traitement, et le HR et le PCV étaient tous deux prédictifs de la survie. Des paramètres simples tels que HR et PCV fournissent des informations utiles pour la gestion des cas de coliques.

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Introduction

Most equine gastrointestinal colic episodes resolve spontaneously or with medical treatment. However, for cases that require surgical intervention, minimizing delays increases survival. Therefore, early identification and treatment of horses with surgical forms of colic remains a key challenge for the equine practitioner (1,2).

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Equine colic surgery has been performed routinely since the mid-1960s (3), and success rates of colic surgery have improved significantly; however, colic continues to be a major cause of morbidity and mortality in the horse (4). The interval between the onset of colic and exploratory celiotomy, the nature of the underlying disease, and the presence of shock and toxemia greatly influence the presence of complications (1,5).

Physical and laboratory parameters can aid in identifying horses that require surgery. Transrectal abdominal palpation, evaluation of pain, response to analgesics, abdominocentesis results, cardiovascular and systemic status, presence of nasogastric reflux, ultrasonography, and other parameters are considered in deciding whether a horse requires surgical treatment (6,7).

In a study in which cases were designated as surgical *versus* medical based on transrectal abdominal palpation and packed cell volume (PCV) findings, the sensitivity and specificity were only 52 and 95%, respectively (8). In another study, based on multivariable logistic regression, critical cases were associated with 5 features: pain, heart rate, capillary refill time, weak pulse, and the absence of gastrointestinal sounds (9). Studies

Table 1. Characteristics of horses in the study; age was expressed as mean ± standard deviation, whereas other variables were expressed as median (and range).

	All	Small intestinal surgical cases < 5 h	Small intestinal surgical cases > 5 h	Large intestinal surgical cases	Surgically treated cases	Medically treated cases
Group	1 to 4	1	2	3	1 to 3	4
Number of cases (%)	125 (100%)	12 (10%)	17 (14%)	(26%)	61 (49%)	64 (51%)
Age (y)	9.7 ± 4.7	12.3 ± 5.6	10.1 ± 4.3	10.1 ± 5.4	10.5 ± 5.1	9.0 ± 4.1
Sex						
Mare *n* (%)	44 (35%)	2 (17%)	6 (35%)	10 (31%)	18 (30%)	26 (41%)
Gelding *n* (%)	52 (42%)	7 (58%)	7 (41%)	(19%)	20 (33%)	32 (50%)
Stallion *n* (%)	29 (23%)	3 (25%)	4 (24%)	16 (50%)	23 (38%)	6 (9%)
Colic duration before presentation (h)	10 (3 to 288)	4 (3 to 5)	12 (8 to 26)	24.5 (6 to 288)	12 (3 to 288)	8 (2 to 120)
PCV (%)	42 (28 to 72)	40[b,d] (32 to 54)	52[d,e] (40 to 72)	47.5[b,e,h] (28 to 72)	48[j] (28 to 72)	40[j,e,h] (30 to 57)
HR (bpm)	60 (34 to 120)	72 (38 to 100)	80[f,g] (60 to 110)	71[f,i] (36 to 120)	75[k] (36 to 120)	48[k,g,i] (34 to 100)
Survivors (%)	98 (78%)	12 (100%)	4 (24%)	22 (69%)	38 (62%)	60 (94%)
PCV of survivors (%)	40[a] (28 to 72)	40 (32 to 54)	49 (40 to 50)	42 (28 to 72)	42[l] (28 to 72)	40 (30 to 52)
PCV of non-survivors (%)	52[a] (40 to 72)	/	58 (48 to 72)	49.5 (40 to 54)	52[l] (40 to 72)	46 (43 to 57)
HR of survivors (bpm)	56[b] (34 to 100)	72 (38 to 100)	74 (60 to 84)	67.5 (36 to 100)	70 (36 to 100)	48 (34 to 80)
HR of non-survivors (bpm)	80[b] (50 to 120)	/	80 (60 to 110)	77.5 (50 to 120)	80 (50 to 120)	85 (64 to 100)
Colic duration of survivors (h)	8[c] (3 to 288)	4 (3 to 5)	10 (8 to 15)	16 (6 to 288)	11 (3 to 288)	8 (2 to 120)
Colic duration of non-survivors (h)	18[c] (5 to 54)	/	12 (8 to 26)	33 (10 to 54)	20 (8 to 54)	13.5 (5 to 32)
Most common breeds *(n)*	Lip (21), Cross (19), Trot (14), Hol (10), Cold (10)	Lip (3), Cross (2), Ar (2), Hol (2)	Cold (4), Cross (3)	Lip (15), Cold (4)	Lip (18), Mix (8), Cold (8), Hol (4)	Trot (12), Cross (11), Han (4), Hol (4)

n — Number; Ar — Arab; bpm — Beats per minute; Cold — Coldblooded; Cross — Crossbred; Han — Hanoveranian; Hol — Holstein; HR — Heart rate; Lip — Lipizzaner; PCV — Packed cell volume; Trot — Trotter; / — Not applicable.
[a,b,c,d,e,f,g,h,i,j,k,l] Differences between groups ($P < 0.05$).

also evaluated hemoglobin and lactate in peritoneal fluid for designating surgical *versus* medical cases (10–12).

In an emergency situation, prompt decisions might be more easily made if reconsidering changes in simple parameters such as heart rate (HR) and PCV. The objective of this prospective case-control study was to determine whether PCV and HR can predict type of treatment and short-term survival (prior to patient discharge) in horses with gastrointestinal tract-induced colic. The duration of colic before presentation was also considered to evaluate its effects on HR and PCV.

Materials and methods

Animals

This prospective case-control study included 125 horses admitted to an equine teaching hospital for gastrointestinal colic. All clients gave informed consent for inclusion in the study. Breed, sex, and age of the horse, and the duration of colic signs were recorded. Soon after arrival, HR and spun PCV (microhematocrit) were measured; the latter was obtained by microhematocrit tube centrifugation with a Type HC 242 centrifuge (Tehtnica, Zelezniki, Slovenia).

The degree of pain was assessed according to a standardized pain scoring system, by 2 experienced equine practitioners (VKK, PK). Pain was graded as mild if the horse responded to nonsteroidal anti-inflammatory drugs, e.g., flunixin meglumine 1 mg/kg, q12h, IV (Super's Diana S.L., Barcelona, Spain), and metamizole sodium 20 mg/kg, q6h, IV (Richter Pharma AG, Wels, Austria), and/or spasmolytics such as hyoscine (scopolamine) butylbromide 0.3 mg/kg, q6h, IV (Boehringer Ingelheim, Ingelheim am Rein, Germany), or if signs of pain were not evident in the following 6 h. If the horse initially responded to nonsteroidal anti-inflammatories but pain recurred after several hours, the pain was classified as moderate. If the horse responded only briefly or not at all to the α2-adrenergic agonist detomidine hydrochloride 0.005 mg/kg/h (Eurovet Animal Health BV, AE Bladel, The Netherlands) with the opioid butorphanol 0.01 mg/kg/h, IV (Richter Pharma AG), the pain was classified as severe.

A tentative diagnosis was made by results of a clinical examination that included transrectal abdominal palpation, evaluation of nasogastric reflux, ultrasonography, abdominocentesis, and peritoneal fluid evaluation, or during surgery. Survival to discharge (i.e., up to 3 wk) was recorded.

The study population was allocated into 4 groups: Group 1 included surgically treated small intestinal cases with < 5 h of colic before presentation and surgery; Group 2 were surgically treated small intestinal cases with > 5 h of colic before presentation and surgery; Group 3 were surgically treated large intestinal

cases; and Group 4 were medically treated cases. Both PCV and HR were compared among groups of horses.

Medical treatment

Medically treated horses received nasogastric intubation with fluid (8 L/500 kg) and/or liquid paraffin (Pharmachem, Ljubljana, Slovenia), IV fluids 1 to 10 L/h (Braun, Melsungen, Germany), spasmolytic hyoscine (scopolamine) butylbromide, IV (Boehringer Ingelheim) and/or analgesic lidocaine 1.3 mg/kg in first 15 min, then 0.05 mg/kg/min in next 24 h, IV (AstraZeneca, London, UK). Controlled hand walking or lunging was done. For cases of uncontrollable pain, the analgesic flunixin meglumine, IV (Super's Diana S.L.), the α2-agonist detomidine hydrochloride, IV (Eurovet Animal Health BV), the anti-inflammatory metamizole, IV (Richter Pharma AG), and/or a combination of metamizole with hyoscine (scopolamine) butylbromide, IV (Richter Pharma AG) were administered. In horses with endotoxemia, the antibiotics penicillin 50 to 100 × 10^3 units/kg/12h, IM (Genera d.d. Rakov Potok, Croatia) and/or gentamicin 6 mg/kg/24 h IV (Genera d.d.) were also used.

Surgical treatment

Preoperative treatment consisted of nasogastric intubation and intravenous administration of fluids 10 L/h (Braun), and antibiotics penicillin 50 to 100 × 10^3 units/kg, q12h, IM (Genera d.d.), and/or gentamicin 6 mg/kg, q24h, IV (Krka d.d., Novo Mesto, Slovenia). After sedation with detomidine hydrochloride 1 mg/100 kg, IV (Eurovet Animal Health BV) and butorphanol 1 mg/100 kg, IV (Richter Pharma AG), general anesthesia was induced with midazolam 0.04 mg/kg, IV (LEK d.d., Ljubljana, Slovenia) and ketamine 2.2 mg/100 kg, IV (Vétoquinol Biowet, Gorzow, Poland), and maintained with isoflurane (Chemical Iberica PV, Salamanca, Spain). A median laparotomy was performed, and the intestines were explored systematically, starting with either the ileum *via* the ileocecal plica in cases of small intestinal strangulation or starting with exploration of the position of the pelvic flexure of the ascending colon in cases of large intestinal displacement/obstruction. A distended cecum and other parts of the intestine were decompressed with a 1.8-mm needle before resection or repositioning. In large intestinal obstruction/displacement cases, evacuation and lavage of the contents was made on the pelvic flexure of the ascending colon. Closure of the linea alba was performed in a simple continuous pattern with absorbable sutures (Medtronic, Dublin, Ireland). Horses were left for an unassisted recovery from anesthesia.

Postoperative management varied and depended on clinical signs recorded after surgery. Clinicopathological signs were recorded hourly for the first 24 h after surgery. In general, fluid therapy, prokinetics, anti-inflammatory drugs, antibiotics, and nasogastric tube for reflux evacuation were administered as needed.

Statistical analyses

Statistical analyses were performed using commercial software (SPSS, Chicago, Illinois, USA). Normality of parametric data was tested using the Shapiro-Wilk test. Because PCV and HR data were often not normally distributed, Kruskal-Wallis H-test and Mann-Whitney U-test were used to compare among groups. The predictive ability of the parameters was investigated with binary logistic regression to predict the type of treatment and survival. Statistical significance was $P < 0.05$.

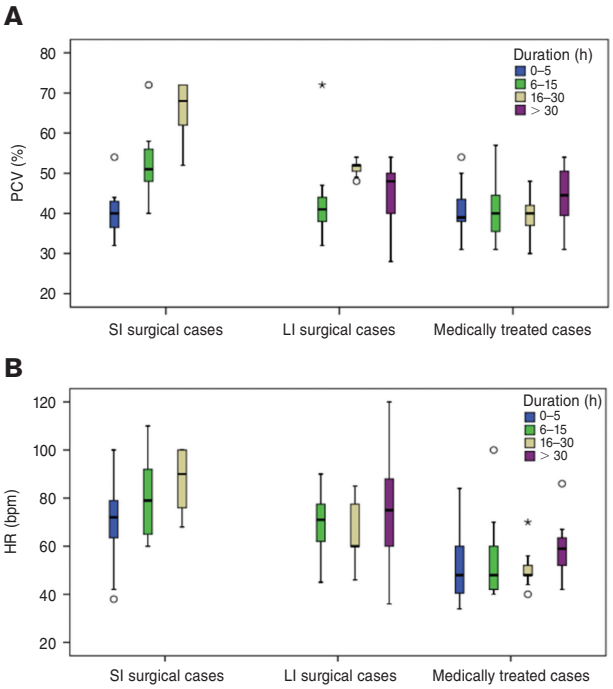

Figure 1. Box-and-whisker plots of packed cell volume (PCV) and heart rate (HR) regarding duration of colic before presentation in 3 groups of horses: small intestinal surgical cases (SI), large intestinal (LI) surgical cases, and medically treated cases. Boxplots display data as follows: The box is the interquartile range (IQR) or middle 50% of the data. The bottom of the box is the first (lower) quartile, the horizontal line in the box represents the median, and the top of the box is the third (upper) quartile. The whiskers are the ranges for the lower 25% and the upper 25% of the data values, excluding outliers (the minimum score i.e., the lower whisker, is calculated as the lower quartile − 1.5 × IQR and the maximum score, i.e., the upper whisker, is calculated as the upper quartile + 1.5 × IQR). The circles and asterisks indicate outliers, i.e., data that are numerically distant from the rest of the data and are outside the whiskers of the boxplot; asterisks are low and high extreme values (more than 3-times the IQR below the first and above the third quartile, respectively) and circles are low and high potential outliers (more than 1.5-times the IQR but not more than 3-times the IQR below the first and above the third quartile, respectively).

Results

Animal characteristics and diagnoses

The 125 horses with colic (Table 1) included 44 mares, 52 geldings, and 29 stallions. Their average age was 9.7 ± 4.7 y, and the most common breeds were Lipizzaner, Crossbred, Trotter, Holstein, and Coldblooded.

There were 12 horses in Group 1, 17 horses in Group 2, 32 horses in Group 3, and 64 horses in Group 4. Among groups, there were no significant differences in age. However, there were more Lipizzaner stallions in Group 3 than with the other groups (Table 1).

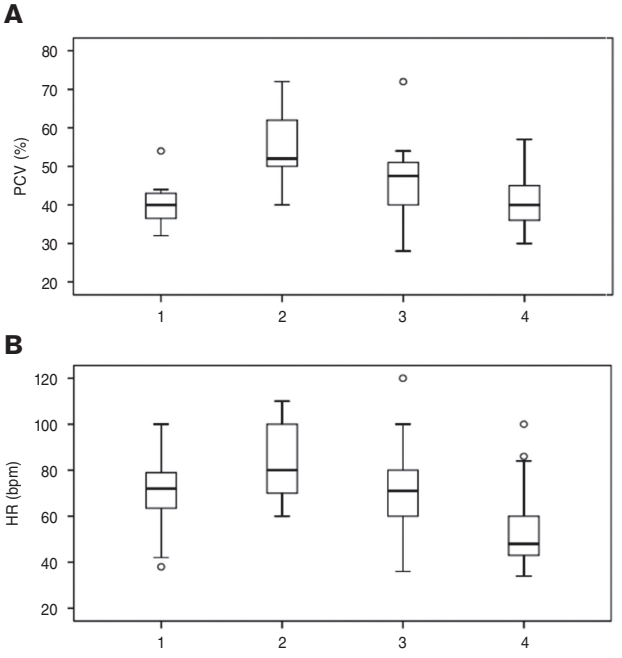

Figure 2. Box-and-whisker plots of packed cell volume (PCV) and heart rate (HR) in the 4 groups of horses with colic. 1 = surgically treated small intestinal cases with < 5 h of duration before surgery; 2 = surgically treated small intestinal cases with > 5 h of duration before surgery; 3 = surgically treated large intestinal cases; and 4 = medically treated cases.

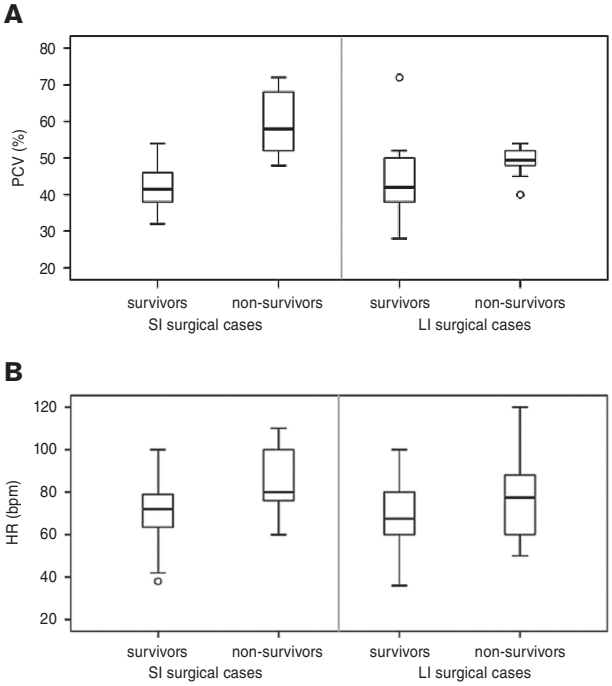

Figure 3. Box-and-whisker plots of packed cell volume (PCV) and heart rate (HR) in surgically treated cases of horses with colic (SI – Small intestine; LI – Large intestine).

Sixty-four horses were treated medically and 61 surgically (29 and 32 for the small and large intestine, respectively). The 29 surgically treated small intestinal cases included inguinal hernia of jejunum (n = 7), ileum impaction (n = 6), strangulation [volvulus, intussusception (ileocecal or jejunal), mesenteric torsion] (n = 9), epiploic foramen entrapment of ileum and jejunum (n = 5), and pedunculated lipoma (n = 2). Of the 32 surgically treated large intestinal cases, the most common causes were paralytic ileus of the colon (n = 11), left dorsal displacement (n = 7), and tympanic colon (n = 5). Although the latter is not a typical surgical lesion if there was no response to medical treatment, surgery was most likely inevitable. Less common large intestinal surgical diagnoses were nephrosplenic entrapment (n = 4), colonic torsion (n = 3), and right dorsal displacement (n = 2). Most nephrosplenic entrapment cases (n = 12) were treated medically with intravenous administration of fluids, analgesics, and spasmolytics, plus hand walking. Other common diagnoses of medically treated cases were colonic impaction (n = 33) and spastic colic (n = 12).

Comparison of PCV and HR among groups of horses

Mean PCV and HR values (with range) for the various groups of horses are presented in Table 1 and Figures 1–3. Both PCV and HR at admission were higher in horses treated surgically than in horses treated medically ($P < 0.001$). Likewise, the PCV and the HR were both higher in the non-survivors than in the survivors ($P < 0.001$) (Table 1). Regarding the duration of colic before presentation, the PCV increased in the small intestinal surgical group only ($P < 0.001$) (Figure 1).

Sixteen (55%) of the small intestinal surgical cases, 22 (69%) of the large intestinal surgical cases, and 60 (94%) of the medically treated horses were discharged after treatment (Table 1). The median duration of colic was shorter ($P < 0.001$) in survivors (8 h) than in non-survivors (18 h). The preoperative PCV was higher for Group 2 than for any other group ($P < 0.001$), and there were differences between Groups 1 and 3 (P = 0.03) and Groups 3 and 4 (P = 0.002). However, there was no difference in PCV between Groups 1 and 4 (P = 0.748). Heart rate was lower for Group 4 than for any other group ($P < 0.02$) and differed between Groups 2 and 3 (P = 0.033). Heart rate was highest in Group 2, although it was not significantly different from Group 1 (P = 0.079) (Figure 2). In surgically treated cases, PCV and HR were the highest in non-surviving small intestinal surgical cases. However only PCV was significantly different from all other groups ($P \leq 0.01$), whereas HR was different for the surviving small intestinal and large intestinal surgical cases (P = 0.037 and P = 0.009, respectively) (Figure 3).

Associations between group and HR and PCV

In binary logistic regression, HR was significant for predicting type of treatment [odds ratio (OR) 1.08; 95% confidence interval (CI): 1.045, 1.116; $P < 0.001$], whereas PCV was only marginally significant (OR: 1.046; 95% CI: 0.986, 1.111;

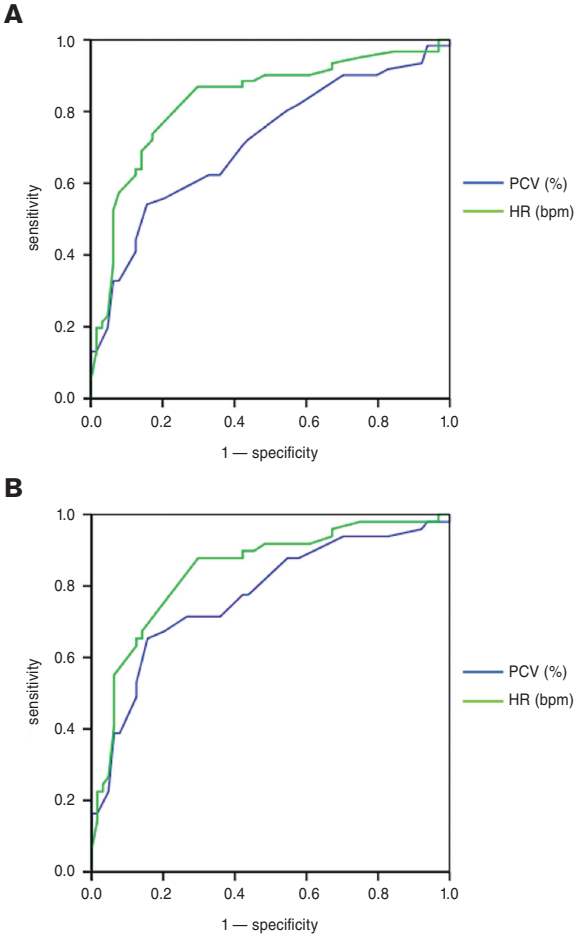

Figure 4. Receiver operating curves of packed cell volume (PCV) (A) and heart rate (HR) (B) as predictors of type of treatment in horses with colic. A – all horses, $n = 125$; and B – horses without Group 1, $n = 113$. Group 1 were surgically treated small intestinal cases with < 5 h of duration before surgery.

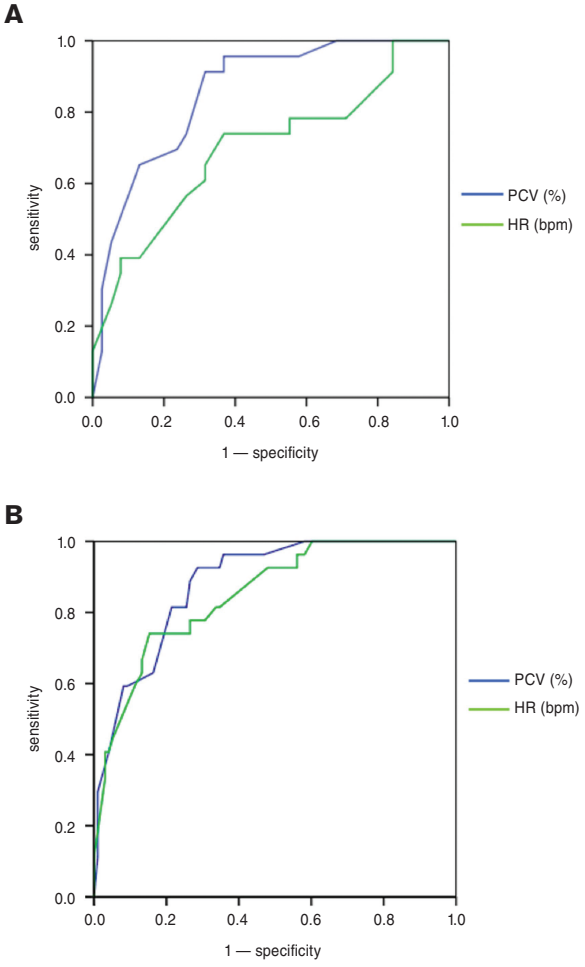

Figure 5. Receiver operating curves of packed cell volume (PCV) and heart rate (HR) as predictors of short-term survival in horses with colic. A – all horses, $n = 125$. B – surgically treated horses, $n = 61$.

$P = 0.137$). To interpret the results: if HR increased by 1 unit, the probability that the case was surgical increased by 8.0%, and if PCV increased by 1 unit, the probability that the case was surgical increased by 4.6%. The sensitivity of the test was 0.77 and the specificity was 0.81. Percentages of correctly classified medically and surgically treated cases were 81.3 and 77.0%, respectively, with overall accuracy of 79.2%. The associated receiver operating characteristic (ROC) curves are in Figure 4 A.

If horses from Group 1 were removed from the binary logistic regression analysis, then both HR and PCV were highly significant (OR_{HR}: 1.075; 95% CI: 1.037, 1.115; $P < 0.001$ and OR_{PCV}: 1.076; 95% CI: 1.005, 1.152; $P = 0.035$, respectively). To interpret the results: if HR increased by 1 unit, the probability that the case was surgical increased by 7.5%, and if PCV increased by 1 unit the probability that the case was surgical increased by 7.6%. The sensitivity of the test was 0.78 and the specificity was 0.83. The percentage of correctly classified medically treated cases was 81.3% and of correctly classified surgically treated cases was 82.2%, and overall accuracy was 77.6%. The associated ROC curves are in Figure 4B.

Furthermore, in binary logistic regression, HR and PCV were both predictive of survival (OR_{HR}: 1.065; 95% CI: 1.024, 1.107; $P = 0.01$ and OR_{PCV}: 1.172; 95% CI: 1.067, 1.287; $P = 0.001$, respectively). To interpret the results: an increase of PCV by 1 unit increased the risk of death by 17.2%, whereas an increase of HR by 1 unit increased the risk of death by 6.5%. The sensitivity of the test was 0.56, specificity was 0.95, percentage of correct surviving cases was 94.9%, and percentage of correct failed cases was 55.6%. Therefore, the model predicted survival much better than failed cases. Overall accuracy was 86.4%. The associated ROC curves are in Figure 5 A.

In horses treated surgically, only PCV was predictive of survival (OR_{HR}: 1.025; 95% CI: 0.984, 1.068; $P = 0.234$ and OR_{PCV}: 1.177; 95% CI: 1.058, 1.308; $P = 0.003$, respectively). To interpret the results: an increase of PCV by 1 unit increased the risk of death by 17.7%. The sensitivity was 0.65 and the

specificity was 0.89. The percentage of correctly classifying survival cases was 89.5% and of correctly classifying non-surviving cases was 65.2%, which means that the model predicted survival better than non-surviving cases. The overall accuracy was 80.3%. The associated ROC curves are in Figure 5 B.

Discussion

At admission, both PCV and HR were higher in horses treated surgically than in horses treated medically, and there was a significant association between HR and the type of treatment, whereas the association of PCV was only marginally significant.

An association of an elevated PCV with surgical cases has been reported (8,13). Deciding whether a surgical lesion is present can be more difficult in early cases with low-grade signs of colic, absence of reflux, and lack of abdominal abnormalities detected on transrectal palpation (6). Regarding effects of duration of colic before presentation, the PCV increased only in the small intestinal surgical group. The probable reason for this finding is the much higher prevalence of complete strangulation in the small intestinal surgical group. In addition, it is possible, but further studies would be needed, to confirm that lesions of the small intestine lead to a complete strangulation more rapidly than those of the large intestine.

From a clinical viewpoint, the significant elevation of PCV in the second group was of great importance. The severity, site, and length of the strangulation/infarction, and the time of colic duration influenced PCV elevation. In addition, low PCV values in the horses in the first group were expected to increase over time despite medical treatment, because surgical small intestinal cases were mostly strangulated cases that deteriorated rapidly and required immediate surgery. In this study, this difference in PCV regarding the duration of colic before presentation between large and small intestinal surgical cases can most likely be attributed to the feature that in large intestinal colic there were fewer cases of strangulation and displacement lesions and more cases of endotoxemia, whereas strangulating lesions predominated with small intestinal cases. In strangulating lesions, a large volume of fluid is sequestered into the intestinal lumen orad to the strangulation, causing reflux and rapid dehydration and elevation of the PCV (6). In contrast, in many cases of severe colic of the large intestine (e.g., colonic atony) the PCV remained low because there was no strangulation lesion. We were able to resolve most cases of endotoxemia (colonic atony) medically but there were also some that still required surgery to empty the intestinal contents after prolonged medical treatment. In surgically treated cases, time is critical for survival (1,5); therefore, a rapid diagnosis must be made. In cases of endotoxemia, hypovolemic shock is common, depending on severity and duration, but the condition improves with medical treatment. In medically treated horses, if there was doubt that the horse would respond to medical treatment, the PCV and HR could be repeated every hour to decide whether other treatments are necessary. However, studies would be needed to confirm this assumption.

Time is a factor that can alter the expected outcome, and the main reason why most clinicians proceed to surgery or euthanasia is the lack of pain control. Classifying horses into 4 groups, as in the present study, aids in further actions and decisions. Recognizing horses in Group 2 warrants a frank discussion with the owner due to their poor prognosis. In our study, only 23.5% of the horses in Group 2 survived. Early recognition of horses in Group 1 improved the survival of small intestinal surgical cases, 100% of horses in Group 1 survived in our study, where only HR was different between the horses in Group 1 and those treated medically. The HR rises with the progression of colic, in part due to pain, but mainly due to a decreased circulating volume secondary to dehydration, a decreased preload from hypotension, and endotoxemia (2). The HR is measured over time, and its response to analgesic therapy is determined and if HR continues to rise despite adequate analgesia, that is considered a surgical indication (6). With hypovolemia, the HR increases to improve tissue perfusion; this is often accompanied by a decrease in pulse quality, pale mucous membranes, and a prolonged capillary refill time (6).

The PCV is a measure of hydration status, with a range of 37 to 42% in normal adult horses not living at high altitudes (14). However, PCV may also be elevated due to splenic contraction, which is common in critically ill and stressed horses. Increasing values over repeated examinations are considered important in horses with colic. Abnormally high values of PCV are most common in horses with abdominal pain, endotoxemia, rhabdomyolysis, and, on rare occasion, horses that have absolute polycythaemia. In our study, PCV was measured by centrifugation of a microhematocrit tube (spun PCV), which is a direct measurement, whereas automated PCV is calculated. Spun PCV values are 1 to 3% higher than automated PCV values, because plasma is trapped in the erythrocytes.

A decision for referral or for surgery is best based on a negative response to analgesics. If HR is considered a potential marker for pain, our study supported this decision. Regardless, limitations of using only individual parameters to determine a diagnosis have been well-documented (15,16). Transrectal abdominal palpation remains one of the most useful diagnostic tools for the evaluation of horses with colic; identification of anatomical landmarks and familiarity with the normal characters of the viscera are essential for differential diagnosis of an acute abdomen. Whereas transrectal abdominal palpation reveals anatomical and functional abnormalities in the caudal abdominal cavity, nasogastric intubation provides information about the amount, color, and odor of reflux. Nasogastric intubation can be a life-saving and informative procedure but is not always associated with surgical cases. In our experience, surgically treated small intestinal cases with colic lasting up to 5 h before surgery usually do not have substantial amount of reflux, although huge amounts of reflux are possible in medical colics involving the small intestine. Large amounts of dark brown gastric reflux and/or foul odor indicates an obstruction of the small intestine, either mechanical or functional, but it may also be associated with a large intestinal problem (6).

Ultrasonography is accurate for evaluation of small and large intestinal forms of colic (17–19); however, transrectal abdominal palpation remains the main diagnostic tool for evaluation of the status of the abdominal viscera in the standing horse, especially in ambulatory practice (6). However, transrectal palpation is

not always possible or necessary. Furthermore, several studies reported a relationship between the characteristics of the peritoneal fluid and the likelihood of a surgical lesion (10–12), and peritoneal fluid evaluation is of crucial significance in determining the need for surgery in horses with colic. However, abdominocentesis can be challenging in some horses with colic.

In our study, 62% of surgical cases (55% of the small intestinal group and 69% of the large intestinal group) and 94% of the medically treated horses were discharged after treatment. The percentage of surviving cases in our study was not the overall rate of survival in horses with colic, because this was a prospective study and horses that were euthanized immediately due to a poor prognosis and/or cost were not included. Nevertheless, our survival rates were in accordance with other studies (16,20–24).

In our study, the median duration of the colic was significantly shorter in survivors (8 h) than in non-survivors (18 h). This was an expected finding, since horses with acute surgical colic deteriorate quickly and shorter survival has been previously linked to longer duration of colic (25,26). Conversely, in other studies, the duration of colic was not associated with survival (5,27,28).

In this study, PCV and HR were both higher in non-survivors than in survivors, consistent with other studies (13,27). However, a statistical difference between the means of the 2 groups does not necessarily ensure the predictive ability of the test. There are limitations of using only individual parameters to predict survival; consequently, multivariable logistic regression models have been employed to determine the association between findings and survival (16,29). In our study, HR and PCV were both predictive of survival if all 125 horses were included. Conversely, if only surgically treated horses were analyzed, then only PCV was predictive of survival, although HR was higher in non-survivors [80 beats per minute (bpm)] compared to survivors (70 bpm). It is likely that the number of surgically treated horses (n = 61) was insufficient to confirm a possible predictive value of HR.

Numerous studies have attempted to evaluate associations between examination findings and survival; however, results have not been consistent. In some studies, both PCV and HR were predictive of increased mortality (16,29,30), whereas in others, only PCV (26,31) or only HR was predictive of survival (4,25,32). In studies evaluating the risk for postoperative ileus, an increased PCV was 1 of the variables associated with an increased risk, whereas HR was not (33,34). Similarly, an increased PCV was associated with decreased survival of horses that underwent a second exploratory laparotomy (35).

In our study, both PCV and HR were valuable simple parameters that should have a crucial role in decisions regarding the treatment of horses with colic. However, it is necessary to confirm the results in a separate validation study. Furthermore, the capacity of PCV and HR as a tool for the prediction of correct treatment should be tested against other clinical variables in a multivariable model. To distinguish horses that need medical or surgical treatment, HR and PCV should be used in conjunction with other information obtained by transrectal abdominal palpation, evaluation of pain and response to analgesics, blood tests, peritoneal fluid evaluation, abdominal ultrasonography, nasogastric intubation, etc. These are all important factors for identification of horses that need surgery.

This study had several limitations. A major limitation was the relatively limited number of patients and therefore logistic regression models with smaller groups of horses (e.g., with $<$ 5 h colic duration before surgery) were not possible. Another major limitation is that we did not include other results of colic diagnostics in our analysis, such as mucous membrane color, capillary refill time, total solids, peritoneal fluid analysis, results of transrectal abdominal palpation, ultrasonographic results, presence of reflux, and others. Furthermore, long-term survival was not included.

Despite the limitations, a simple guide for the clinician can be derived. If a horse does not respond to analgesics and the PCV rises to $>$ 48% in a short interval (e.g., 1 h) despite fluid therapy, the likelihood of a strangulating small intestinal lesion is high. In contrast, if after 10 L of IV fluids the PCV decreases $>$ 4%, this is a good prognostic sign. Large intestinal surgical cases that were not immediately recognized as surgical were initially treated medically, and when the large intestinal case became surgical after a prolonged interval ($>$ 12 h), it was because clinical parameters had deteriorated, although PCV only occasionally exceeded 48%. In our experience, PCV does not increase in 5 to 8 h in patients undergoing large intestinal surgery, except in cases of colonic torsion. In other large intestinal displacements, in our experience, the PCV does not increase so fast (5 to 8 h), and when it increases, it does so to a lesser extent. In addition, our experience is that with strangulating small intestinal lesions, IV, and/or enteral administration of fluids does not decrease PCV.

Unfortunately, we did not recognize the importance of including serial measurements in our manuscript. However, as shown in Figure 1, comparison of PCV and HR in the 3 groups of horses (i.e., small intestinal surgical, large intestinal surgical, and medically treated cases) with respect to owner-reported duration of colic indicated that PCV increased with duration of colic before presentation only in the small intestinal surgical group. Further studies involving serial measurements of HR and PCV are needed to confirm that as duration of colic increases, PCV and HR increase only in the small intestinal surgical group. In addition, total solids were measured in all colic patients, but we did not include them in our analysis. Our experience is that total solids usually have a delayed response to an acute colic (usually $>$ 5 h) because time is needed for accumulation of inflammatory proteins). The conditions with discrepancies between PCV and total solids, which are either surgical or medical cases, are recognized by other clinical signs (fever, response to analgesics, diarrhea, etc.). For example, in horses with acute colitis, which is a common cause of rapid debilitation and death in horses, PCV and TS are elevated, and the horses have fever and within several hours, large amounts of diarrhea. In horses with colic, changes in body temperature may be attributed to increased activity due to pain, a local or systemic inflammatory response, or inadequate cardiovascular function and an increase in rectal temperature decreases the risk that surgery is needed (8).

In conclusion, our results provided useful information for colic cases in which an early decision to pursue surgical

treatment is of crucial importance for survival of surgically managed cases. The decision is best based on a diagnosis; however, a definitive diagnosis is not always possible, and HR and PCV should, in conjunction with other findings, guide decisions regarding treatment.

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